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**A UNIQUE METHOD FOR MONITORING
CABIN AIR POLLUTION FROM ENGINE
OIL IN THE EB-57D AIRCRAFT**

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FOREWORD

This report was prepared by the Analytical Branch, Materials Physics Division, Air Force Materials Laboratory (LPA). This work was initiated under Project No. 7360, "Chemical, Physical and Thermodynamic Properties of Aircraft, Missile and Spacecraft Materials," Task No. 736005, "Compositional, Atomic and Molecular Analysis of Experimental Materials for Advanced Air Force Systems," by William J. Crawford and Capt. Henry A. Wells.

This report covers work performed between September 1968 and July 1970.

The authors wish to acknowledge Robert J. Govenar (ASD/ENCCE) for securing the samples from the various aircraft for chemical analysis. Also, we would like to acknowledge the fine cooperation given us by the EB-57D 4677th Defense Systems Evaluation Squadron located at Hill Air Force Base, Utah and, in particular, Maj. Gus Von Wolffradt.

This report was submitted by the authors October, 1972.

This technical report has been reviewed and is approved.

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ABSTRACT

A simple reliable method for monitoring engine oil pollution in aircraft cabin atmospheres is presented. The method involves use of a specially designed sampling device and a standard quantitative infrared spectroscopic procedure. The report describes the use of this device to evaluate an air decontamination system on the EB-57D aircraft. A catalytic filter has been recommended for use in the EB-57D aircraft to lower the oil content in the cabin atmosphere.

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SECTION I

INTRODUCTION

For a number of years the EB-57D aircraft has had a continual problem with cabin atmosphere pollution in the form of smoke and oil mist, particularly at high engine power levels and high cabin temperatures. In particular, the 4677th Defense Systems Evaluation Squadron (DSES), ADC, Hill AFB, Utah, which uses the EB-57D, had been living with the problem. However, in 1968, a change in the squadron's mission required use of the A/P22S-2 full pressure suit. This caused concern over a potential fire hazard, since the oil deposited in the suit by the contaminated ventilation system might subsequently come into contact with the pure oxygen used in pre- and post-flight suit pressure checks.

To avoid this potential hazard, the EB-57D Systems Support Manager (SSM), Warner Robins AMA, had a Mine Safety Appliance (MSA) catalytic filter installed on an EB-57D. This appeared to clear up the problem but testing was undertaken to obtain a quantitative estimate of the filter's efficiency. The method employed used a carbon tetrachloride scrubber and determination of hydrocarbons as hexane based on the 2940 cm^{-1} absorption band in the carbon tetrachloride solutions. This procedure detected some oil in the air ventilation system but the results were inconsistent; in some cases detecting more oil after the filter than before.

At this point the Analytical Branch, Air Force Materials Laboratory, was asked to propose alternate sampling procedures to evaluate the filter. Also, a committee of combustion experts (Chaired by Dr. Karl Scheller, Aerospace Research Laboratory/ARC) was designated to evaluate the results obtained with the catalytic filter equipped EB-57D aircraft.

SECTION II

SELECTION OF PROCEDURE

Since the oil concentration values would be meaningless without a reference or standard, the committee recommended using an F-104 aircraft as a control. The F-104 aircraft was considered to have an acceptably clean cabin environment.

Initially, mass spectrometry or gas chromatography were considered as possible analytical methods to detect and measure the oil concentration but when standard gas collection bottles were used to sample the cabin atmospheres no oil could be detected in the gas samples. Since the oil could be visually observed in the aircraft cabin as an atomized material, the apparent problem was collecting a representative sample and then transferring the material from the collector into the mass spectrometer. After a few tests it was evident a special collector was needed to sample the cabin atmosphere.

An idea was proposed to pass the cabin air through a cold trap and collect the oil. A series of tests revealed the atomized oil could not be easily trapped and the apparatus seemed unstable for in-flight use. The next approach was to pass the cabin air through a tube containing an absorbent and absorb the oil on to the absorbent. Then, the absorbent was to be removed from the tube and the oil desorbed with a solvent, the oil concentrated and some type of quantitative analysis performed.

The final sample collector, chosen after a series of tests with various tube lengths and absorbent particle sizes, is shown in Figure 1. The disassembled collector is shown in Figure 2. The collector is assembled by first placing the copper wire screen in the AN919-18J union which has the copper tube attached. Next, assemble the tube to the union and insert a small wad of glass wool in the other end of the tube. Push the glass wool down the tube until it lodges at the fitting. Now, proceed to fill the tube with the absorbent, tapping the sides of the tube during the filling process. After the tube is filled, place a

small wad of glass wool on the absorbent and attach the union with the hose connector. The assembled unit is now placed in an airtight plastic bag and sealed. The collector is delivered to the aircraft, removed from the plastic bag and installed. It was necessary to have an Air Force drawing made and the collector was assigned Air Force part number x69C319. The drawing is shown in Figure 3.

The sample collector is installed in the aircraft by plugging the hose from the ventilation system into the hose connector and attaching the tygon hose to the aircraft relief valve. The collector is installed prior to each flight. A log showing the number of flight hours is kept for each sample so that the accumulation of oil may be expressed as a function of flight time.

SECTION III EXPERIMENTAL

A. SUPPLIES

- (1) Sampling tube as described in drawings
- (2) Firebrick: 100 gm/tube - Particle size, 30-40 mesh - Source, Matheson, Coleman & Bell
- (3) Glass wool
- (4) Copper wire screen
- (5) Spectroquality carbon tetrachloride - 500 ml/sample - Source, Matheson, Coleman & Bell
- (6) 500 ml standard American Society for Testing Materials (ASTM) extraction apparatus (soxhlet extractor) and thimbles
- (7) Hot plate or heating mantle for extractor operating to at least 80° C
- (8) 500 ml beaker(s)
- (9) 25 ml beaker(s)
- (10) 3 - 25 ml or 10 ml volumetric flasks
- (11) MIL-E-7808 oil sample
- (12) Infrared spectrophotometer operating at 1730 cm^{-1}
- (13) 1.0 mm path sealed infrared cell transparent at 1730 cm^{-1} , preferably NaCl
- (14) Infrared crystal, transparent over range of spectrophotometer

B. PREPARATION OF MATERIALS

The 1.0 mm cell should be scanned empty to determine that the windows are clean. The exact thickness should be determined by interference fringes, if observable, or by transmission of a standard solvent. The thickness and cleanliness of the cell must periodically

be checked to insure standardization of the method. The carbon tetrachloride may be checked by evaporating 500 ml to dryness, adding 1 ml of clean solvent and scanning the region near 1730 cm^{-1} . The concentrated solvent should show no increase in transmission over an unconcentrated blank at 1730 cm^{-1} .

The firebrick is prepared by a 100 cycle extraction against clean carbon tetrachloride. All metal parts of the tube should be thoroughly washed with carbon tetrachloride and tubes should be sealed in clean containers for shipment to and from the sampling site.

C. STANDARDIZATION

A working curve should be prepared for the 1730 cm^{-1} absorption of MIL-E-7808 oil according to standard procedures. It is most convenient if this curve is linear but it is really only important that it be reproducible. The authors used a Perkin-Elmer 521 spectrophotometer, which produces a very linear curve when run at the manufacturer's survey settings. For a 1.0 mm cell, standards in the concentration range of 1 mg/ml should produce reasonable absorption values. The authors prefer the use of a single cell, run twice, with and without sample, on the same chart, to compensated methods since the latter are inherently less reliable. A reference curve of pure MIL-E-7808 oil spread on a suitable salt plate should also be recorded over the range of the instrument.

D. PROCEDURE

Upon receipt of a sample, the tube is opened, the firebrick and glass wool are transferred quantitatively into the extraction thimble with carbon tetrachloride and the soxhlet is cycled about 100 times at 80°C . The carbon tetrachloride is then evaporated to or near dryness and more solvent is added to produce an accurately known volume of solution. This solution is then run in the desired frequency range superimposed upon a blank solvent scan. The proper final solution volume must be determined by trial and error to give a band of desirable intensity. In practice,

comparing solution color to the standards used in making up the working curve will often suffice to prepare a solution of the proper concentration. Otherwise, several concentrations may be tried by quantitative recovery of the sample from the cell.

If the working curve is linear, an oil index such as the product of the optical density at 1730 cm^{-1} , the final solution volume and the path length is sufficient for further use. If, however, the working curve is not linear, the actual quantity of oil collected should be calculated.

SECTION IV

RESULTS AND DISCUSSION

Figure 4 shows a plot of oil index, as previously defined, versus hours of flight time for the five aircraft used in this study. Six types of points appear since aircraft #968 was sampled both before and after MSA filter installation. The scale is chosen to give a high slope to the lines of oil accumulation for those aircraft described as "dirty" by the pilots of the 4677th DSES. Since this results in virtually zero slopes for the filtered B-57's and the F-104, this part of the data is replotted in Figure 5 on an expanded scale. The sampling was not extended beyond the 100 hrs shown in the figures. The authors felt that the distinction between the "clean" and "dirty" groups was clearly established at this point and sufficient for meaningful inter-group comparison.

Checks on the identity of the compound responsible for the 1730 cm^{-1} absorption, as described previously, indicated that the "dirty" aircraft were contaminated primarily with MIL-E-7808 engine oil. In most of the samples plotted in Figure 5, however, the principle ester present was an alkyl phthalate, presumably leaching out of the plastic tubing in the aircraft ventilation system, and MIL-E-7808 was undetectable.

The use of an arbitrary oil index in these plots, rather than expressing the contamination directly in milligrams of oil collected, was a carefully considered step. Since there was no reasonable procedure for calibrating our collection method, short of constructing an apparatus duplicating the ventilation system and cabin of the EB-57D into which oil could be introduced in accurately measured quantitative and particle sizes, the method is valid only for comparison between samples.

In particular, the differing collection efficiencies of the pressure suit and the collector, the different flow rates through them, and the possible different response of oil flow to the different air flow conditions all contribute to an unknown proportionality constant between

oil collected and suit contamination. For this reason, conclusive results can only be obtained by plotting the accumulation of oil vs time for both a subject and standard aircraft. Likewise, the method's blank must be determined by extrapolation of these plots back to zero time since there is no apparatus to duplicate the sampling conditions without the oil. Therefore, since considerable difficulty was encountered trying to convince untrained personnel that the absolute collection figures were not meaningful, we settled on use of a dimensionless index proportional to collected oil. This had the effect of forcing the data users to make valid multipoint comparisons and protecting them from the dangers of single point-absolute value conclusions.

SECTION V
CONCLUSIONS

The data of Figures 4 and 5 clearly demonstrate that the MSA catalytic filter does significantly lower the oil content of the cabin ventilation system to a level comparable to or below that of the background ester concentration present in such acceptable aircraft as the F-104. It is, therefore, reasonable to assume that installation of these filters will eliminate any extraordinary hazard from oil contamination during pressure suit operation. These findings were submitted to the previously mentioned committee of ARL combustion experts who concurred and recommended installation of the filters on all EB-57D aircraft.

The data also indicates that the sampling procedure used here provides a simple, rugged, and inexpensive method for monitoring aircraft atmospheres for hydrocarbon contamination.

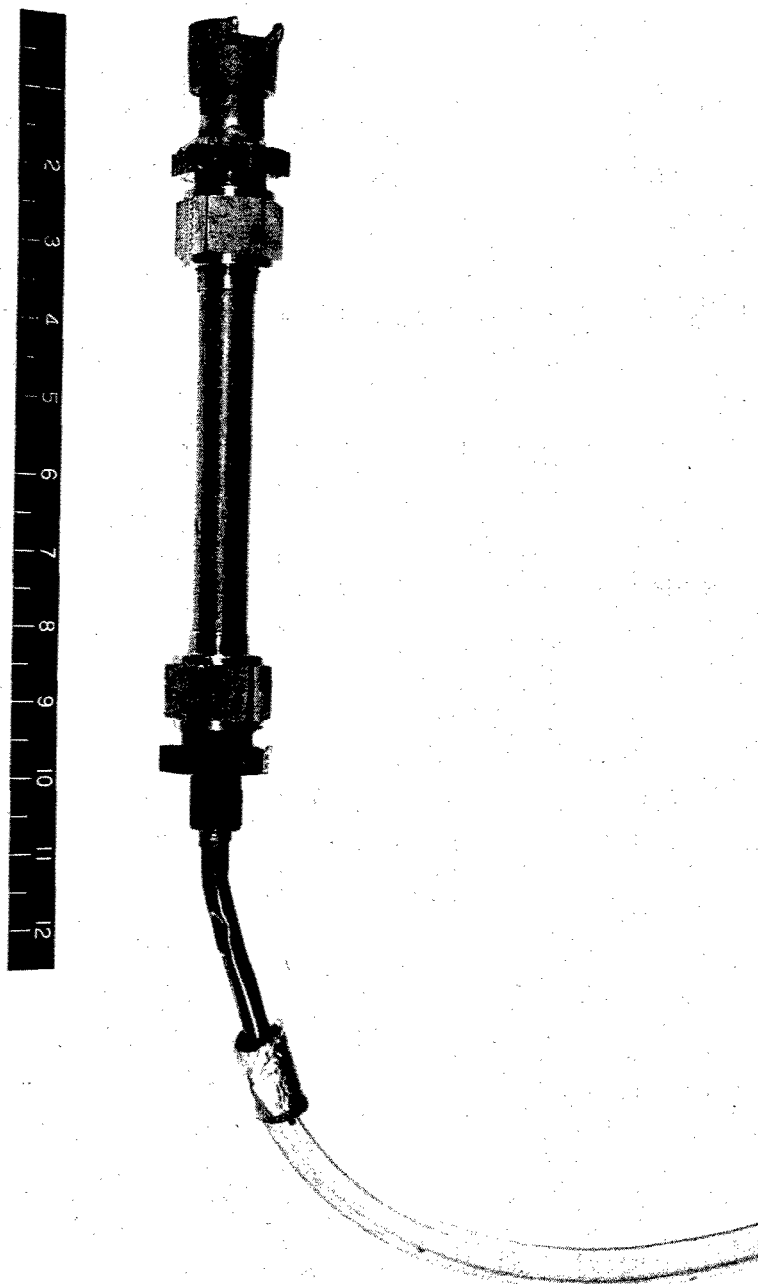


Figure 1. Assembled Gas Sample Collector

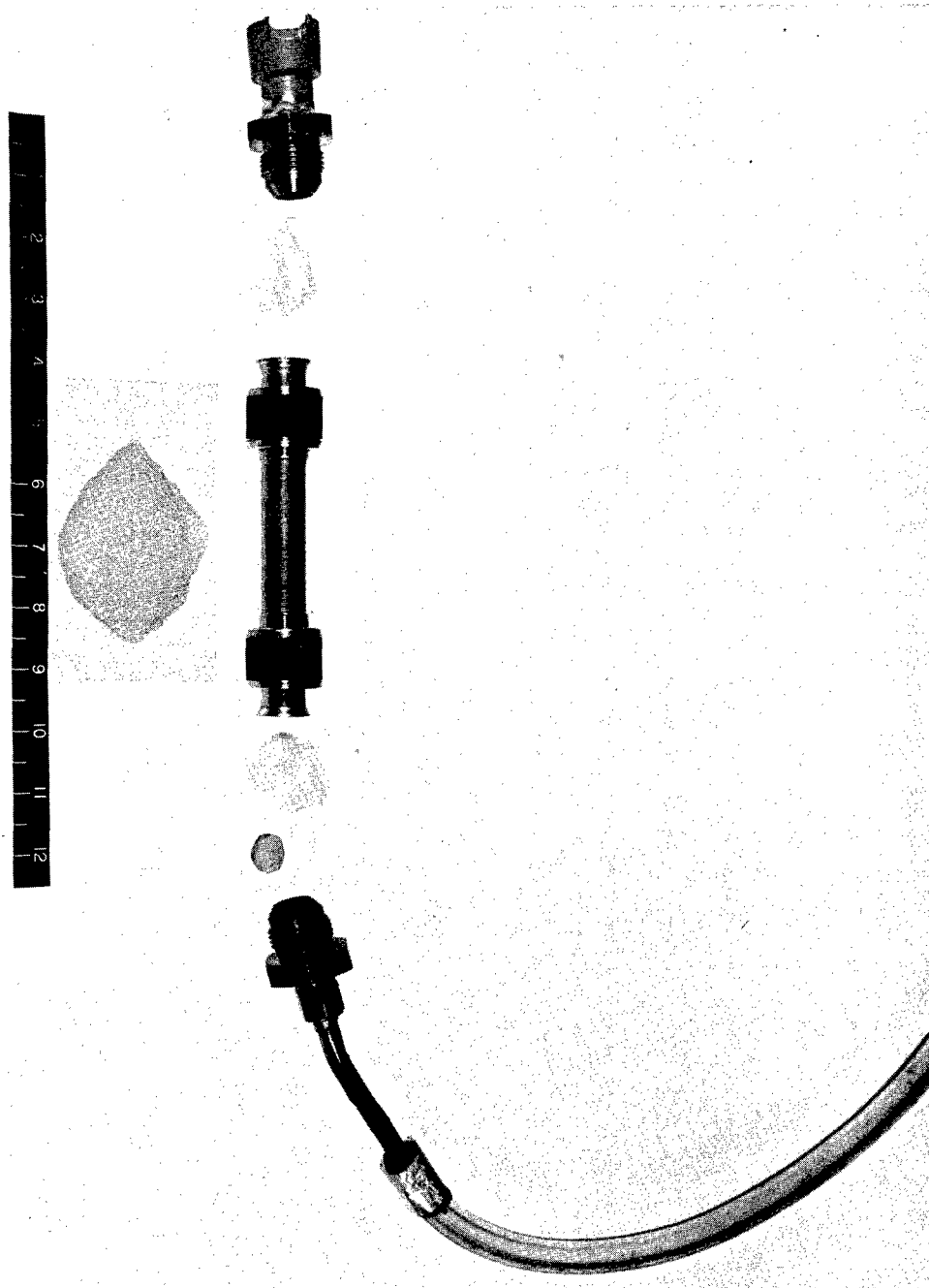


Figure 2. Exploded View of Gas Sample Collector

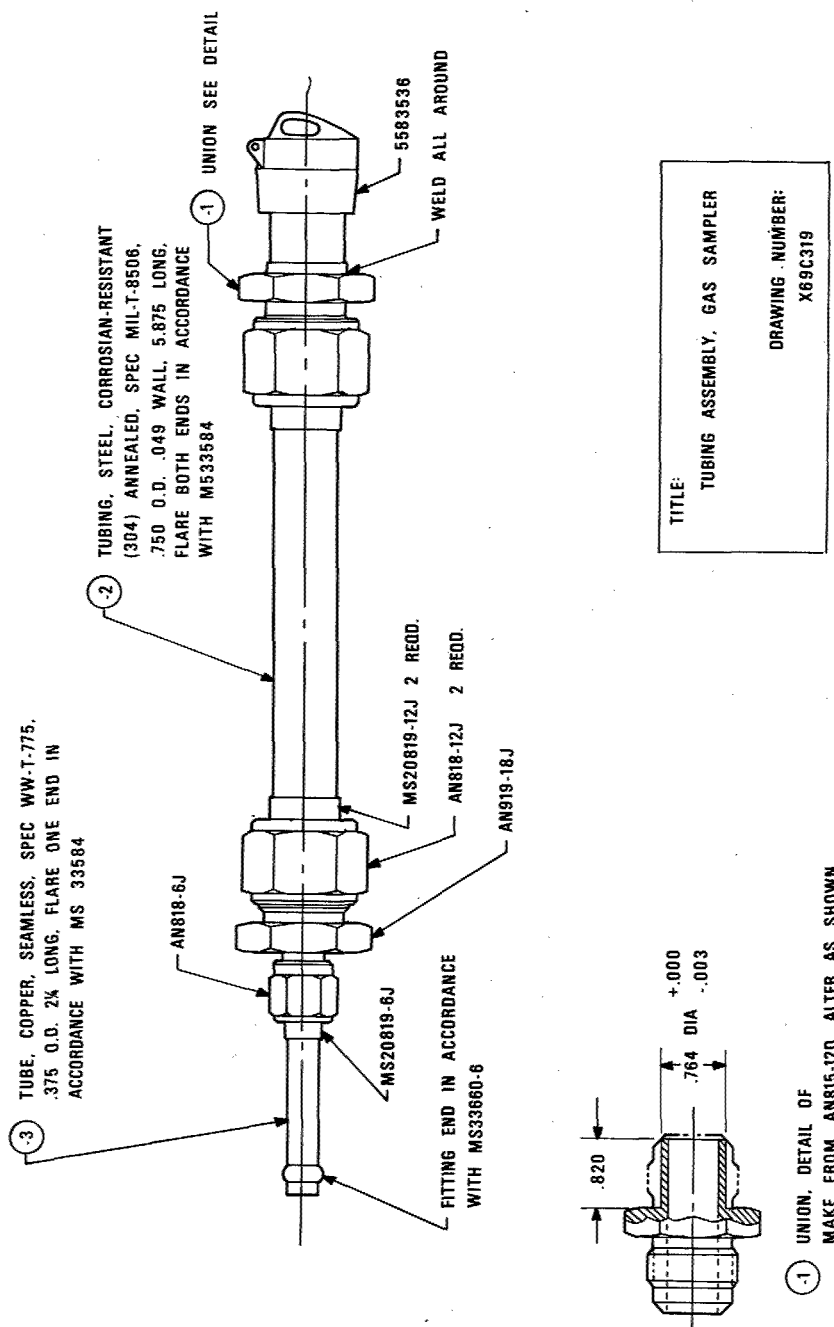


Figure 3. Drawing of Gas Sample Collector

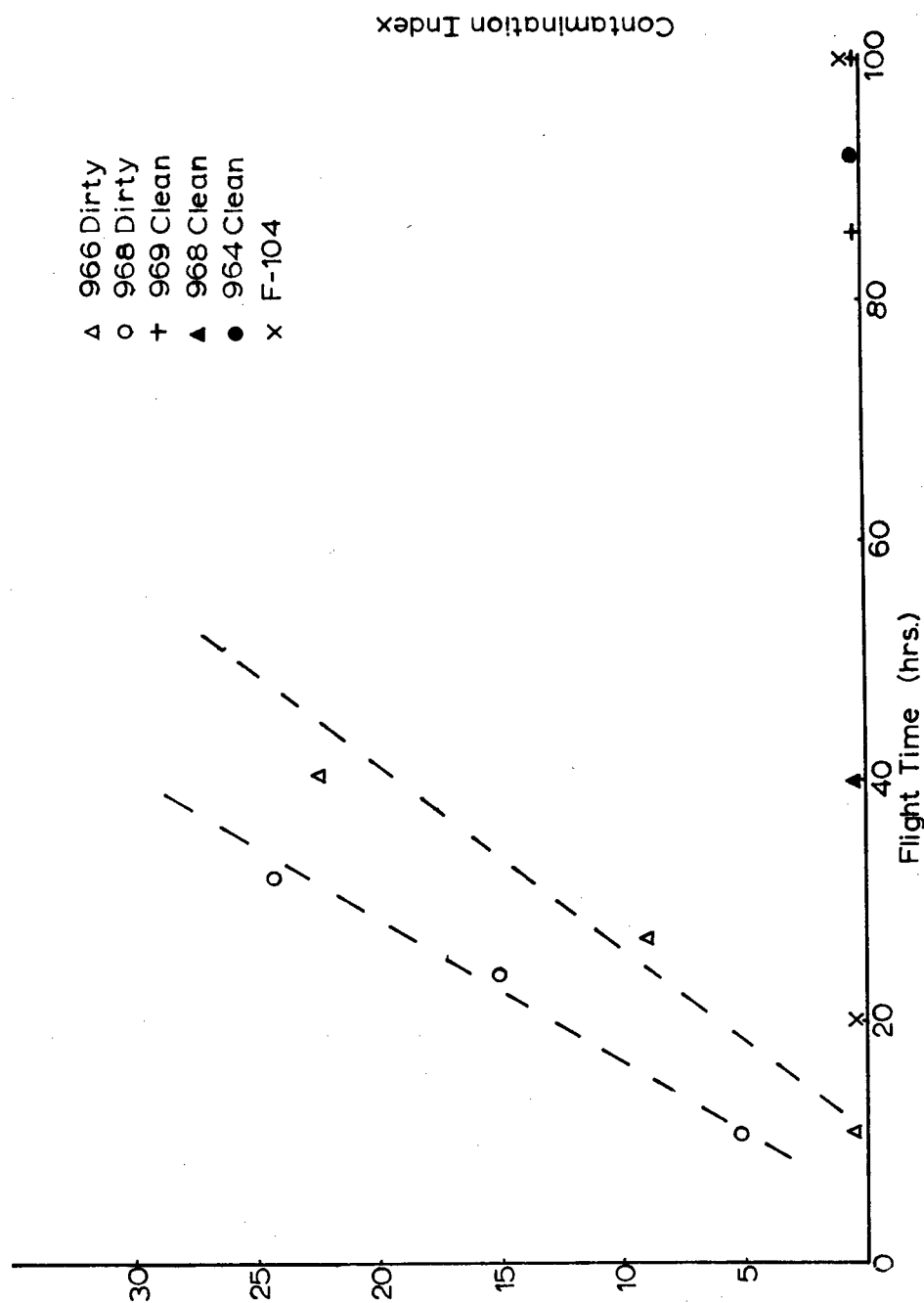


Figure 4. Graph of Oil Index Versus Flight Time Comparing "Clean" and "Dirty" Aircraft

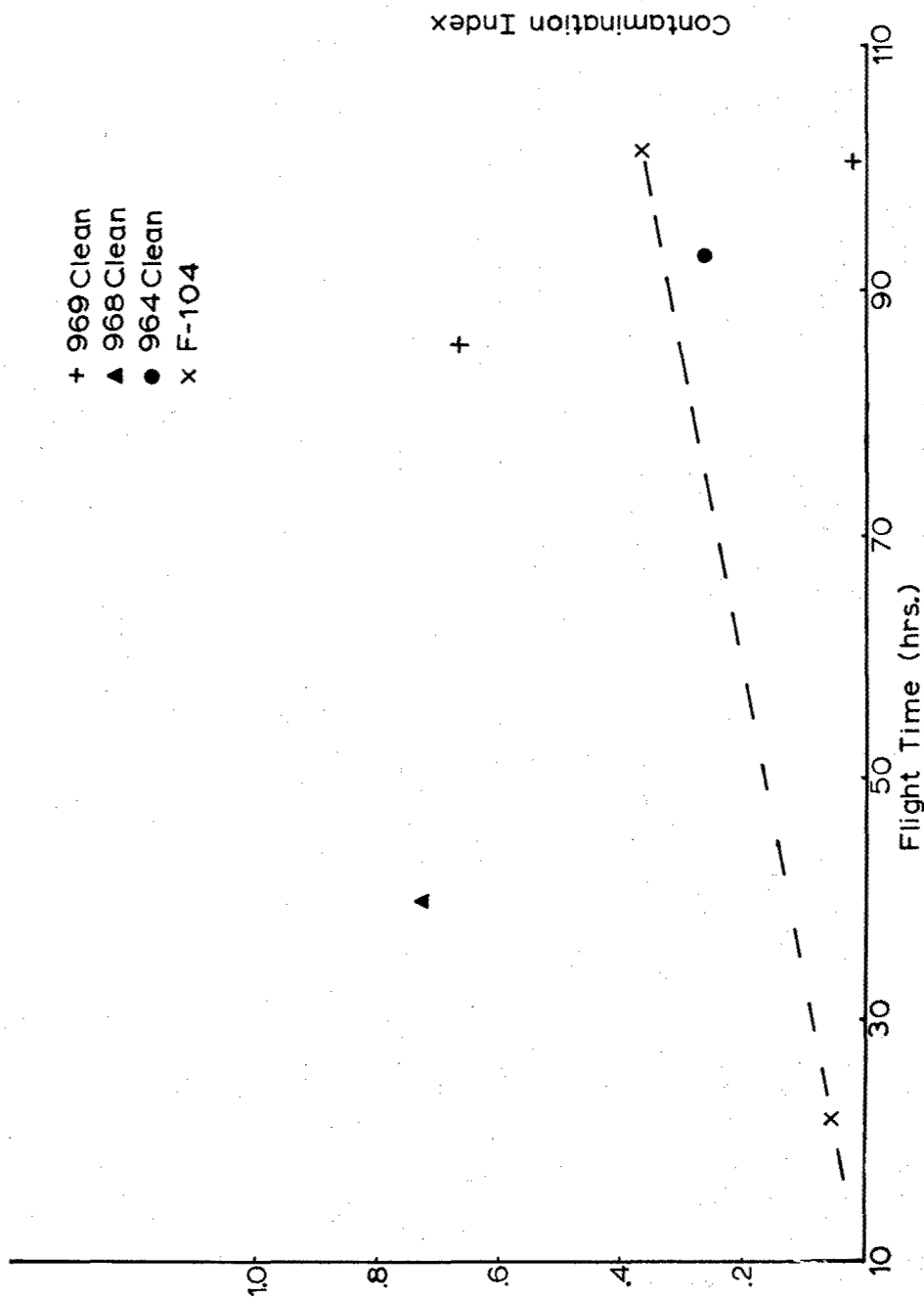


Figure 5. Expanded Scale of Oil Index Versus Flight Time for "Clean" Aircraft

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